ELECTRONIC PATIENT RECORD SYSTEM

A Master's Paper in
Computer Science

by

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ABSTRACT

This paper designs an electronic patient record application as part of the Hospital Information System. This application is different from the currently used applications by building it on the World Wide Web instead of on an Intranet. There are six user levels in the design: administrator level, physician level, charge nurse level, nurse level, secretary level, and patient level.

Creating a paperless environment for the Hospital Information System has been a goal for years in the health care industry. The application of this project is web-based. The users of this system log on to the password protected accounts and access the medical data from the database in a paperless environment.

In addition, this system provides an integrated information system for authorized personnel to retrieve necessary medical information anywhere and anytime in a nationwide range. Thus it helps with physicians’ diagnostic decision making.

The implementation runs on an Apache server, accessible world-wide. MySQL is the backend database. The programming languages are PHP, HTML, and Java Script.
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1. Introduction

A Hospital Information System requires helpful technical tools in data gathering, storage, transmission, processing, reference, and analysis. The hospital information technologies (HIT) are software-based applications.

As early as the 1960's, a variety of information technologies was adopted for the purpose of improving health care quality, reducing unnecessary costs, and improving operations. The hospital information system technologies in the early days were not very practical because of the expense and complexity of the computer technology.

Today’s health care information systems in the United States use computer-related technologies in the administration, management, and the provision of patient care. The problem with the existing systems is that they are unconnected, cumbersome, not interoperable, and not user friendly. They involve mostly data entry without a GUI interface. The existing systems are independent of each other. The administrative system does not network with the management system. A transition is needed to empower the health practitioners. The clinical information system is the addition to the ideal design of hospital information system.

A clinical information system is centered around patients, physicians, nurses, and clinical processes. It integrates with administration and management system. With such synergy, the integration of digital data becomes the key issue. Thus the Internet is required for the networking. In this integrated information system the authorized personnel can retrieve necessary information anywhere and anytime [29], and read the notes of other physicians with permission. Thus, authorized personnel are able to make reliable decisions on patient diagnoses/prescriptions. In summary, in an ideal situation the integrated application would be the center of the Hospital Information System. The goal of this project is to implement one part of a clinical information system - Electronic Patient Record (EPR).
1.1 Traditional Information Storage in the Clinical System

The traditional information storage method is paper-based. For instance, it is very common that patient records are created in the emergency room upon admission in a paper-based system. The duplicates of the same records are made manually in the main hospital. All the records on file are charted eventually and put away in the storage room. Not only does filing records take a significant amount of time and space, but the information look-up can sometimes also become impossible [34].

The idea of an Intranet was introduced after the emergence of the Internet around the 1970s-1980s. Intranets have been used in hospitals as a transition to the integrated hospital information system. An Intranet is the Internet with controlled access, featuring broad bandwidth, and high security. These qualities are essential for the health care industry. However, Intranet does not have the convenience of accessing data anywhere or anytime. Intranet does not provide global communications [14]. An Intranet does not make documents available instantaneously to authorized users. The World Wide Web is a more desirable approach for better health care, and EPR is set for reaching this goal of universal access.

1.2 A Standard Medical Term System

In the current hospital information system, for the benefit of medical study, as well as communication among physicians among different hospitals regarding patient care, a standard medical term system is needed. In the United States, efforts are being made to improve hospital information systems. The U.S. Department of Health and Human Services (HHS) signed an agreement with the College of American Pathologists (CAP) in Northfield, Illinois, to license its standardized medical vocabulary system and make it available free of charge throughout the United States as a digital database [24]. This $32.4 million dollar contract allows permanent public access to the digital database for its highly recognized standardized medical terms, namely SNOMED RT. SNOMED RT will be further discussed later on in this project. HHS has also commissioned the Institute of Medicine in Washington to design a standardized electronic health record application,
1.3 The Motivation and Contribution of Electronic Patient Record (EPR)

The primary motivation for designing an electronic patient record system is to provide a practical, user-friendly, and powerful application for health care professionals. The rapid progress in computerization by banking and other financial systems inspired the development of hospital information system. At present, the hospital information system is not comparable with the advanced banking system. There are various on-going software applications applied in hospitals, but the existing systems are not satisfactory. The health care professional is in need of a helpful application to assist them with better patient care.

With the introduction of Electronic Patient Record system, many informational problems in the existing system will be solved. The ultimate goal is to improve the health care system and reduce administrative cost. In brief, the Electronic Patient Record provides a paperless environment in the hospital. All users of the Electronic Patient Record system are able to access the online records anywhere and anytime via the Internet. All medical records and other patients’ files are stored in a centralized database. The application is user-friendly. Certain sensitive values are in read only format. It also provides error-checking and information retrieval.

The contributions of this project are:

- It provides a paperless environment, which improves the traditional records storage methods;
- All patients’ records are filed and stored in an online database, which speeds up the work flow in the hospital;
- It is a centralized system, which assists physicians with decision-making, through patient searching engine and diagnostic writing tool within the hospital;
- A secretary writes directly into the central database doing patient scheduling.
The charge nurse writes directly into the central database doing nurse scheduling, which reduces file redundancy;

- The project is built entirely on open sources;
- It features error-checking of dates, such as date of birth, and many more functions which will be presented in details later on.

This project is only a partial design and implementation of the Electronic Patient Record system. It doesn’t include order entry, laboratory image processing, but includes patients’ personal background, patient scheduling and diagnostic related matters. A complete EPR system will also involve a billing system, patients’ food and nutrition supply, patients’ transportation supply and much more. Here the focus is solely on the basic structure of the hospital information system. There are six user levels in the EPR system. Each one has its distinct job function. The EPR system is only accessible by registered users, and the patient records are available anywhere any time as long as an Internet connection is established.

1.4 The Organization

The rest of the paper is organized as follows. In chapter 2, we present an overview of an electronic patient record system. In chapter 3, we detail the EPR components and interface. Chapter 4 describes the EPR front foundation and backend support. In chapter 5, we discuss EPR security. Finally, we conclude the paper and discuss future development.
2. Electronic Patient Record (EPR)

2.1 EPR is Driven by the Quality and Efficiency of Health Care

The goal of designing EPR is to improve the quality and efficiency of health care and to integrate electronic data via the Internet. The introduction of EPR is to improve data distribution time and to cut back on printing costs and paper waste.

Electronic patient record (EPR) is an electronic data repository of a patient’s lifetime health status and health care, being stored so that it becomes available to the legitimate users of the record in the system [7]. It is a tool to link different resources for decision support. It aggregates a patient’s medical data for the purpose of the health care.

EPR meets the needs of physicians, nurses, and patients in the health care information system:

- Physicians are the direct users of the system. The emphasis of EPR on physician users is significantly different from the previous era of hospital information systems, in which the clerks/secretaries were the main users for scheduling patients and generating bills. EPR also provides references look-up regarding patient medical information [2] for diagnostic decision support.

- Nurse users appreciate an application with a centric non-keyboard and non-data entry screen with GUI interface. EPR will provide a more automated system for the nurse users in order to set nurses free from a lot of documentation work. Nurses will have more time to work at patient care.

- Patient users will be able to access their diagnose/prescription anywhere and anytime. Patients are able to update their personal information stored in the database as well.

All the above scenarios could be done easily if they are connected to the Internet.
2.2 Terminology Problem

To implement an electronic hospital information system, a standardized terminology for medical data is needed. There are some current “terminology problems” in health care.

- The researchers find a lack of information in existing claims data;
- The information system developers need a standard terminology for implementing the coded diagnostic documentation in the computerization of health care products;
- The administrative level needs more detailed data on how patients are being taken care of, in order to manage implementation guidelines and best practices [31].

2.3 Introducing SNOMED CT

SNOMED International, the Systematized Nomenclature of Human and Veterinary Medicine, began to develop more than 20 years ago. SNOMED CT (Clinical Terminology) is rich in its concepts which includes “anatomy (topography), morphology (pathologic structure), normal and abnormal functions, symptoms and signs of disease, chemicals, drugs, enzymes and other body proteins, living organisms, physical agents, spatial relationships, occupations, social contexts, diseases/diagnoses and procedures, and more” [3]. One of the outstanding features of these terms is that the concepts defined in the terminology have cross-references to each other. As a natural terminology SNOMED CT is semantical and hierarchical. SNOMED CT is the pioneer for coded data as computer-readable format in the health care applications. In general, SNOMED forms a tremendous starting point for the future development of a unified and standard digital database [3]. This ideal digital database will be utilized in the future health care information system design.

The framework of SNOMED is described as SNOMED RT (Reference Terminology) [18]. SNOMED RT is designed with enhanced features such that it enables user interfaces, electronic messaging, or natural language processing, as well as from other non-clinical data representation in a hierarchical form [31]. The study of SNOMED RT is
beyond the scope of this project. In brief, SNOMED RT represents multiple hierarchies and incorporates description logic. It is believed that SNOMED concepts with multiple levels of granularity and multiple logic-based subsumption hierarchies can meet the potential requirements of a reference terminology for modern health care system [31].

SNOMED RT parent/child hierarchy Example:

<table>
<thead>
<tr>
<th>Child</th>
<th>Relationship</th>
<th>Parent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronary artery</td>
<td>is a part of</td>
<td>Heart</td>
</tr>
<tr>
<td>Heart</td>
<td>is a part of</td>
<td>Cardiovascular system</td>
</tr>
<tr>
<td>Cardiovascular system</td>
<td>is a part of</td>
<td>Body system</td>
</tr>
<tr>
<td>Body system</td>
<td>is a part of</td>
<td>Physical anatomical entity</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Child</th>
<th>Relationship</th>
<th>Parent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atherosclerosis</td>
<td>is a</td>
<td>Vascular sclerosis</td>
</tr>
<tr>
<td>Vascular sclerosis</td>
<td>is a</td>
<td>Degenerative abnormality</td>
</tr>
<tr>
<td>Degenerative abnormality</td>
<td>is a</td>
<td>Morphology</td>
</tr>
</tbody>
</table>

Table 2.1 SNOMED RT Parent/child Example

SNOMED Clinical Terminology (SNOMED CT), based on SNOMED RT, is a comprehensive and precise clinical reference terminology. It was released in June, 2001. SNOMED CT encompasses clinical terminology in a hierarchical database. It offers [6]:

- more than 352,000 fully specified concepts,
- more than 939,000 descriptions (or synonyms),
- the breadth of both primary and specialized care,
- the extension to specialty medicine,
- the assurance of medical data accuracy, availability, integrity and reliability.

SNOMED CT is a natural terminology solution that makes healthcare information accessible and usable whenever and wherever it is needed. Its capability of standardizing data is revolutionary. What makes SNOMED CT's standardization essential is:

- the consistent aggregation of clinical patient care information,
- the retrieval of information for disease management and research study,
- the conducting of outcome analysis for health care quality improvement,
As mentioned earlier, HHS has signed a $42.3 million worth of contract with CAP for the release of SNOMED CT for public free access. Since SNOMED CT is or will be the standard terminology for medical data, EPR has used SNOMED CT as part of the design. The appearance of SNOMED CT can be seen in the diagnosis section. The intention is to provide EPR users (such as, physicians, nurses, and patients) with the standard medical term to avoid misunderstanding in diagnostic related terms. Unfortunately, SNOMED CT is not going to be released for public access until January, 2004. Since this project was implemented in 2003, readers are not provided with the actual SNOMED CT term at this time. Here is part of the reply received upon request for the access to SNOMED CT.

“... regarding access to the SNOMED content. Have you heard that the NLM (The National Library of Medicine) recently executed an agreement with the CAP to allow for free use of SNOMED Core content in the U.S. through the UMLS effective January of 2004? Until such time, SNOMED must be licensed from the CAP at a cost of $500 for the remainder of 2003. ” [4]

2.4 EPR Functionality

Moving towards a paperless environment, EPR is designed to:

- guide clinical professionals to make appropriate decisions,
- act as references during subsequent consultations,
- provide simultaneous access to the same record for health care professionals for the purpose of patient care,
- store and transfer records more efficiently than paper-based records,
- support clinical scientific research,
- support of structured data entry,
- provide easier data retrieval than paper-based patient records,
- reduce possible medical errors.
2.5 Paperless vs. Paper-based Hospital Information System

Studies have shown that paper-based records cannot adequately support the efficient patient care service in today’s high technology world [12]. Lack of a standard medical terminology is also an issue with paper-based patient records. Moreover, the problems with “maintaining paper-based patient records” are intensified by “the overloading of general and patient-specific information from many resources”. “Patients with chronic disease charted in bulging records” create potential problems for the paper-based patient records maintenance as well [5].

With a paper-based information storage system, some of the predominant problems include:

- missing patient records,
- poor handwriting conducted by certain physicians and nursing staff,
- use of non-standard abbreviations for medical terms,
- misplaced or lost patient charts,
- multiple versions of documents/forms,
- inability to chart a record right after an event,
- complicated and redundant requirements for documentation [22],
- inconvenience in patient records look-up for decision support,
- difficulty in patient medical data study for the purpose of medical study,
- inefficient patient care directly or indirectly caused by time spent on bulging paper work.

Electronic patient record marks the changes in the modern health care system. It not only solves the above problems existing in the paper-based environment, but also allows patient data to be used for a wide variety of purposes. The electronic patient data can be used among “direct patient care, decision support, quality assurance” (including assessment of the quality of the health care), “scientific research, and management of health care facilities” (including scheduling, billing, food and nutrition supply, transportation supply, and administrative supplies) [11].
The fundamental challenge to the 21st century’s health care system is to provide effective patient care. Another challenge is to avoid misconduct in medical practice. Cost reduction is always a challenge to hospital administrative leaders. Electronic patient record is the answer to one of the challenges facing current health care computing technologies. In electronic patient record application, patient data is presented in a usable [1] and adequate form, with user friendly GUI interface, and is non-keystroke centric.

However, there are trade-offs with the paperless system: too many detailed segments will delay the retrieval of information [8]. Secure Internet access will depend on good technical design, implementation and support for the protection of patient privacy.


## 3. EPR Interface and Components

EPR provides two basic structures: registration and user levels. Registration is where users reset passwords. User levels from top-down are administrator level, physician level, charge nurse level, nurse level, secretary level, and patient level. The administrator level creates and removes users from the database. The physician level writes diagnosis and prescriptions for patients. The charge nurse level schedules nurses for patient care. The nurse level follows the nurse schedule and takes care of certain patients. The secretary level does patient scheduling and information lookup. The patient level provides a patient’s personal background information.

### 3.1 Registration

The registration page enables a first-time user to reset his/her password, providing a valid login name and given password. It also enables the returning-users to reset the passwords anytime. The new password will be encrypted as a 32 character-long string in the database, which prevents the abuse of user access.

---

**REGISTRATION GUIDE**

*Note: For the security purpose, the first time users MUST go to First Time User Register to reset the given password. Failing to do so will result in denial from logging in to the system. Also for the security purpose, returning users are encouraged to reset their password frequently. Consider changing password as changing your toothbrush!*

- [First Time User Register](#)
- [Returning User Reset Password](#)

---

Figure 3.1 Registration Guide
Figure 3.1 is the screen shot of Registration Guide. A note is provided to all users for guidance. The first URL, namely first time user register, leads to the registration stage (shown in Figure 3.2). The second URL, namely returning user reset password, leads to password reset page (shown in Figure 3.3). A user is encouraged to reset his password often for security purpose.
If a user forgets his own password, logging into the system will become impossible. In this case, he has the option of contacting the administrator for a new given password through email passwords. This option is given on the logging in Error message for each user.

3.2 User Levels

There are five different user levels. Users at different levels perform different roles.

- **Administrator Level** - An administrator is capable of adding users to the database system as well of deleting users from it. Users include all levels, such as patient, physician, charge nurse, nurse, secretary and administrator.

- **Physician Level** - A physician is able to search for his/her patient(s), write diagnoses/prescriptions and look up old diagnoses/prescriptions for reference. A physician profile is built with contact information.

- **Charge Nurse Level** - A charge nurse is able to schedule nurses for patient care daily. A charge nurse can look up patients and nurses.

- **Nurse Level** - A nurse logs on to the Nurse level, and she/he checks the daily schedule for the patients to be cared for.

- **Secretary Level** - A secretary is solely responsible for help desk information. A secretary schedules patients with different physicians.

- **Patient Level** - A patient is capable of providing/updating his/her personnel information, and a patient is able to look at the diagnosis or prescriptions as well.

The main intention of categorizing user levels is to maintain the security of the clinical information system. By doing so, it prevents misusage of the role performed in the health care system. In a way, by categorizing user levels, it also speeds up the work flow in the hospital. From the managerial perspective, it clearly classifies the hospital employee and staff group.

EPR Core is the heart of EPR component. The scenario below is the diagram of EPR Component. As shown, EPR Core is a centralized network.
3.3 Administrator Center

The Administrator Center is a tool for administrative management in the EPR application. An administrator organizes his/her work in a paperless environment. He/she has direct access to the database through online forms for data addition or removal.

Validation of the proper username and password are required before an administrator enters the system. After an administrator has been verified, the user will be presented with two main functionalities: “Add a New User” and “Remove a User.” By clicking on the former, it takes the administrator to a form for setting up a new user. When a new patient account is created successfully through the form, the new information will automatically be inserted into the patient table.
<table>
<thead>
<tr>
<th>P_ID</th>
<th>P_Lastname</th>
<th>P_Firstname</th>
<th>MI</th>
<th>Ssn</th>
<th>Dr_ID</th>
<th>Dr_name</th>
<th>Visit_Reason</th>
<th>Visit_Date</th>
<th>Discharge Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>x10001</td>
<td>Bailey</td>
<td>Lois</td>
<td>J</td>
<td>111-11-1111</td>
<td>Phy102</td>
<td>Dr. Simpson</td>
<td>Headache</td>
<td>10/20/03</td>
<td></td>
</tr>
<tr>
<td>x10002</td>
<td>Davidson</td>
<td>David</td>
<td></td>
<td>610-10-1000</td>
<td>Phy101</td>
<td>Dr. Anderson</td>
<td>Cold</td>
<td>10/20/03</td>
<td></td>
</tr>
<tr>
<td>x10003</td>
<td>Lu</td>
<td>Lisa</td>
<td>X</td>
<td>800-80-8000</td>
<td>Phy101</td>
<td>Dr. Anderson</td>
<td>Cold</td>
<td>10/21/03</td>
<td></td>
</tr>
<tr>
<td>x10004</td>
<td>Bailey</td>
<td>George</td>
<td></td>
<td>242-42-4242</td>
<td>Phy102</td>
<td>Dr. Simpson</td>
<td>Allergy</td>
<td>10/21/03</td>
<td></td>
</tr>
<tr>
<td>x10005</td>
<td>Bailey</td>
<td>Lois</td>
<td>L</td>
<td>222-22-2222</td>
<td>Phy101</td>
<td>Dr. Anderson</td>
<td>Heart Problem</td>
<td>10/23/03</td>
<td></td>
</tr>
<tr>
<td>x10006</td>
<td>Davidson</td>
<td>Linda</td>
<td>A</td>
<td>123-45-6789</td>
<td>Phy101</td>
<td>Dr. Anderson</td>
<td>Allergy</td>
<td>10/23/03</td>
<td></td>
</tr>
<tr>
<td>x10007</td>
<td>Davidson</td>
<td>Pam</td>
<td>A</td>
<td>322-32-2424</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3.1 An Instance of Inserting the New Patient x10007 into the Patient Table after Creating a New Patient User

Likewise, when a new physician account is created successfully through the form, the information will be automatically inserted into the physician table. When a new nurse account is created, the information will be automatically inserted into the nurse table.

Figure 3.5 Form to Set up a New User

As shown from the above, User ID is generated automatically in sequence. There is also a drop-down box for selection of user authorization levels. By default, a patient level is selected. For other levels of users, selection must be made accordingly. The submission of a completed form will generate a new user in the database. While any required
information is missing, an error message will be prompted as well as a “go back” option for the user to redo the form.

Figure 3.6 Add a New User Error Message

By clicking on “Remove a User”, it takes the administrator to the form for removing a user exiting in the database. This is where an administrator deletes users.

Figure 3.7 Remove a User
This is very similar to Add a User. The patient level is selected as the default. The submission of a completed form will result in the complete removal of the user from the database. Actions cannot be undone.

The logout function is applied on every stage of the administrator center. An administrator can log out of the system anytime as he/she desires to. The “Back” button is also implemented for the user to go back to the previous stage if he/she decides not to log out. See the screen shot of the log out stage at Figure 3.8.

![EPR Users Logout Page](image)

**Figure 3.8 Logout Page**

If “Yes” is selected, the browser will be directed to Electronic Patient Record's main page. If “Back” is selected, the browser will be directed to the previous stage before the user comes to the log out page.

- Generate pseudo-random new user login name
  - User login name is formed by the first letter of the first name, and the first letter of the last name, followed by a random 4 digit number.
  - For instance, Lisa Lu's login name might be ll2486.
• Generate random user password
  • The password is an 8-character long random string, including lower or uppercase letters, and all the special characters.
  • For instance, a sample password is nRxoMawp.
• Physician ID is generated in sequence
  • Physician ID starts with the string “phy”, followed by a 3-digit number in sequence.
  • Every time a new physician is created in the database, the code picks up the maximum value of the physician ID currently stored, and increments by 1. Thus the system generates the new physician ID.
  • For instance, phy101 and phy102 will be followed by phy103.
• Nurse ID and patient ID are generated in the same fashion as physician ID
  • Instance of nurse ID, nur101, nur102.
  • Instance of patient ID, x10001, x10002.

3.4 Physician Center

Physicians play a major role in the clinical system for patient care. The Physician Center is designed to provide a convenient working station. A physician is able to search for any one of his/her patients. A physician can also look up all the patients under his/her care in addition to edit his/her patient’s profile.

To look up all patients, the physician uses the “See All Patients” link. It will bring up all the patients that are under this physician's care. All patients are listed in an ordered list indexed with Arabic numbers. The representation of a patient is presented with the patient’s ID followed by his/her full name. Each patient name listed is a link directing the physician to a patient’s complete medical record and personal background information.

To look up a specific patient, the physician uses “See a Patient” link. It will take a user to a search form for the specific patient.
The patient search is based on multiple conditions. A search can be done through one or more search keywords. The keywords include a patient’s medical number, a patient’s last name, home location, and a diagnosis.

After bringing up a patient, a physician can work on the patient's diagnosis and prescriptions. The input information will be directly written to the database.

- There are seven main functions:
  - Edit Physician’s Profile
  - Check Patient’s Personal Background
  - Write a Diagnose
  - See a Diagnose
  - Write a Prescription
  - See a Prescription
  - Discharge a Patient
- Diagnoses ID is generated in sequence
  - Diagnose ID starts with a string “dig”, followed by a 3-digit number in
sequence.

- Prescription ID is generated in sequence
  - Prescription ID starts with a string “pre”, followed by a 3-digit number in sequence.
  - After the physician inputs a diagnosis for the patient, he will be linked to the prescription page for further work.

![Figure 3.10 Input a Diagnosis](image)

After submitting the diagnosis, a physician has an option to edit the diagnosis. Fields indicated with asterisk must be filled. All changes made will be written directly to the database.
After the diagnosis is complete, it is linked to the prescription input form. Looking up a diagnosis/prescription is very similar to what is in Patient Center, Nurse Center and Secretary Center, which will be presented later on.
The discharge function is one of the privileges that a physician has. It only applies to in-patients who stay in the hospital. Discharging a patient more than once will result in a reminder message.

![Figure 3.13 Discharge reminder](image)

A physician's profile is the data that relates to his/her professional specialty, office location, and contact information. Figure 3.14 is a screen shot of one example.

![Figure 3.14 Physician Profile](image)
By clicking on “Update”, it brings up the text form for data editing. All fields indicated with asterisk must be filled. Any changes made here will be written directly to the database.

![Figure 3.15 Physician Profile Editing](image)

### 3.5 Charge Nurse Center

The charge nurse center is the workstation for a charge nurse. It is just as convenient working in the office as well as working at home. The interface is designed in an easy-to-use manner. A charge nurse's duty is to schedule nurses to take care of patients. When a charge nurse logs in successfully as an authorized user, there will be three functionalities for the job manipulation: Look up all Nurses, Look up all Patients, and Nurse Scheduling.

“Look up all Nurses” will pull out all the available nurses under the supervision of a charge nurse. The purpose of this function is to have direct access to the nurses available for scheduling. “Look up all Patients” is similar to the former. “Nurse Scheduling” is used to schedule available nurses to take care of patients in the system. The screenshot of Look up all Nurses is illustrated in Figure 3.16.
### Figure 3.16 Nurse Information

Below (Figure 3.17) is the screen shot of Look up all Patients. The web page itself is very self-explanatory. Please note that a discharge date with a blank cell means that the patient is still under care.

#### Figure 3.17 Patient Information

<table>
<thead>
<tr>
<th>Patient ID</th>
<th>Lastname</th>
<th>Firstname</th>
<th>M.I.</th>
<th>Dr. ID</th>
<th>Dr. Name</th>
<th>Dr. Login</th>
<th>Reason of Visit</th>
<th>Visit Date</th>
<th>Discharge Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>x10001</td>
<td>Bailey</td>
<td>Lois</td>
<td>J</td>
<td>phy102</td>
<td>Dr. Simpson</td>
<td>physician</td>
<td>Headache</td>
<td>10/20/2003</td>
<td></td>
</tr>
<tr>
<td>x10002</td>
<td>Davidson</td>
<td>David</td>
<td></td>
<td>phy101</td>
<td>Dr. Anderson</td>
<td>neo</td>
<td>Cold</td>
<td>10/20/2003</td>
<td></td>
</tr>
<tr>
<td>x10003</td>
<td>Lu</td>
<td>Lisa</td>
<td>X</td>
<td>phy101</td>
<td>Dr. Anderson</td>
<td>neo</td>
<td>Cold</td>
<td>10/21/2003</td>
<td></td>
</tr>
<tr>
<td>x10004</td>
<td>Bailey</td>
<td>George</td>
<td></td>
<td>phy101</td>
<td>Dr. Simpson</td>
<td>physician</td>
<td>Allergy</td>
<td>10/21/2003</td>
<td></td>
</tr>
<tr>
<td>x10005</td>
<td>Bailey</td>
<td>Lois</td>
<td>L</td>
<td>phy101</td>
<td>Dr. Anderson</td>
<td>neo</td>
<td>heart problem</td>
<td>10/23/2003</td>
<td></td>
</tr>
<tr>
<td>x10006</td>
<td>Davidson</td>
<td>Linda</td>
<td>A</td>
<td>phy101</td>
<td>Dr. Anderson</td>
<td>neo</td>
<td>allergy</td>
<td>10/23/2003</td>
<td></td>
</tr>
<tr>
<td>x10007</td>
<td>Davidson</td>
<td>Pam</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
All the available nurses are listed next to the patient, scheduling is just a matter of click and submit. The system is basically a selection process. Figure 3.18 shows a screen shot of the Schedule Sheet.

Figure 3.18 Charge Nurse Schedule Sheet

- Generate the current date and time
  - Date and time functions are implemented for the charge nurse work station. When a charge nurse does scheduling, the current time and date will be generated in the schedule sheet.
    - The time is generated in h:m:s format.
    - The date is generated in mm/dd/yyyy format.
- Generate future time
  For the security of patient data protection, the system grants nurses a valid time period to check on their patients’ medical data. This valid time period usually matches a nurse’s daily shift. From the time the schedule starts to the deadline time, a nurse is permitted to his/her patient's medical data. The deadline is eight hours after
the start time which is the beginning of the shift. In reality it varies depending on how the clinical system runs.

3.6 Nurse Center

In the hospital system, a nurse is scheduled to different patients on a daily basis. The content of the patient list on Nurse center is dynamically updated every day. After a nurse logs in successfully, a schedule will be displayed if this nurse has been scheduled. A schedule is a sheet with the information of patients whom are taken care of as this nurse's duty. Figure 3.19 shows this function.

```plaintext
Welcome to Electronic Patient Record Nurse Center

FINAL SCHEDULE ---- January 16, 2004, 3:28 pm

<table>
<thead>
<tr>
<th>Nurse ID</th>
<th>Nurse Scheduled</th>
<th>Patient ID</th>
<th>Patient name</th>
<th>Patient Room</th>
<th>Dr. ID</th>
<th>Dr. Name</th>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>nur101</td>
<td>Marge Simpson</td>
<td>x10002</td>
<td>David Davidson</td>
<td>Rm421 4thFL</td>
<td>phy101</td>
<td>Dr. Anderson</td>
<td>23:58:59</td>
<td>7:58:59 01</td>
</tr>
<tr>
<td>nur101</td>
<td>Marge Simpson</td>
<td>x10004</td>
<td>George Bailey</td>
<td>play102</td>
<td></td>
<td>Dr. Simpson</td>
<td>23:58:59</td>
<td>7:58:59 01</td>
</tr>
</tbody>
</table>

Note: To check out the patient record information, please click on the patient ID.
```

Figure 3.19 Nurse Schedule

Usually, a nurse is assigned up to five patients to take care of daily. By clicking on the patient's ID number, a nurse is able to look at the patient’s medical record for the purpose of patient care. Below is the screen shot of the nurse center after clicking on the patient's
ID. It subsequently brings up the patient's personal and medical records.

A nurse is only able to look at the record of patients whom have been assigned to him/her for that day. This is done by clicking on the patient's identification number. After the time period expires, the records are not accessible any more. Unless the same patient is assigned to him/her again later on. As far as the time period goes, it simply stretches to a nurse's daily work shift.

### 3.7 Secretary Center

Traditionally, a secretary or clerk does the major task of entering data entry into the database. EPR designer intends to have physician user and nurse user as the main focus of this system since physicians and nurses plays major roles in health care.

In this system a secretary mainly plays a help desk role in the system. A secretary, as a non-professional, does not input any medical data to the database since she/he is not on the medical staff. This is one way to prevent inputting wrong data into the system.
There are two main functions:

- **Find a Patient** - It performs an AND logical search. This search agent is a bit different from that of physician users. A secretary is able to search for any patients. A physician is only able to search for his/her own patients. Search is done through one searching category or combination of categories. A search submitted without any information yields an error message. A properly performed search eventually brings up the resulting patient/patients. Furthermore, a secretary enters the patient's record.
  - Check Patient's Personal Background
  - See a Prescription

- **Patient Scheduling** - When new patients enter the system, the physicians are not pre-assigned to them. A secretary must perform this task by scheduling the appropriate physician to each patient.
“Reason of Visit” and “Visit Date” are text fields. “Physician Available” are featured in drop down box. If there are no new patients to be scheduled, it will simply display a message.

Figure 3.22 Schedule a Patient

Figure 3.23 Patient Scheduling Message
As shown from the screen shots provided, there is also a timer display on the schedule sheet. The timer is synchronized to the local standard time.

**3.8 Patient Center**

The intention of the Patient Center is to provide convenient access to patients’ private diagnosis/prescriptions, and to allow them to update their personal background information.

![Figure 3.24 Patient Area](image)

There are four main functions:

- Personal Background
- See a Diagnosis
- See a Prescription
- See the Physician Profile

Patients are able to look at one or multiple diagnosis by doing one or multiple selections. A patient can also check out his physician’s profile. Figure 3.25 is the screen shot of
patient Lois Bailey's Personal Background. The patient’s personal background collects a patient’s bio and contact information.

Figure 3.25 Patient Profile

Electronic Patient Record, Diagnosis Search Results

Note: Please click on a diagnosis number in the display for reading. Use ‘shift’ or ‘control’, then click for multiple diagnosis reading.

Found these entries in the table:

<table>
<thead>
<tr>
<th>Date</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/22/2003</td>
<td>dig110</td>
</tr>
<tr>
<td>10/22/2003</td>
<td>dig111</td>
</tr>
<tr>
<td>10/22/2003</td>
<td>dig112</td>
</tr>
<tr>
<td>10/22/2003</td>
<td>dig113</td>
</tr>
</tbody>
</table>

Search

Figure 3.26 Patient Diagnosis Search
As shown, the diagnosis is identified by date and diagnosis number. By clicking on certain diagnosis, it will bring up the resulting diagnosis.

![Electronic Patient Record, Diagnosis Search Reading](image)

**Figure 3.27 Patient Diagnosis Reading**

The diagnosis also features a printing function. By clicking on “Print Friendly”, a new browser will pop up if it is Internet Explorer or Netscape. Mozilla will simply display the entire diagnosis in a full frame. Thus, a “Back” button is provided for the user to go back to where he/she was. All these apply to the prescription implementation.
4. EPR Front Foundation and Backend Support

4.1 Operating System: Centralized System

EPR is based on a centralized operating system. All the clinical data is maintained in the central database. Data information is under strict revision control. Only users with authorized write permission are able to write to or update the database. This centralized storage system is comparatively fast since there is no expensive network load. It is simply one access point for local, remote, and home working EPR users. Users are always provided with the latest data information available through the centralized server. The system encourages large corporations to embrace open communication for an integrated business operation.

4.2 Programming Language: PHP

This system is implemented using PHP. PHP is the most popular server side scripting language for writing dynamic web pages. It is secure, efficient, and fast to deploy [32]. Since EPR is based on dynamic web application, it is suitable for this project. PHP stands for Hypertext Pre-processor. The abbreviation follows the style set by Richard Stallmann, who is the founder of GNU [23]. As the name implies, PHP is a pre-processor for hypertext, which runs on a remote web server. It processes the web pages before they are sent to the browser [33]. Thus PHP is classified as a server-side scripting language as opposed to a client-side scripting language (for instance, JavaScript). Running on the server has several benefits and some drawbacks.

Advantages:

- On the server side, a user has access to the database. Therefore, a user is able to make a script to sort through large amounts of data, without the client downloading them first.
- PHP-scripts are browser-neutral. The script itself is not sent to the client but the output of the script is. The script is invisible from the end-user as opposed to JavaScript, the client-side scripting (everybody is able to read the script in the source of the webpage). PHP scripts do not depend on some capability of the browser.
- As a server-side scripting language, PHP code is invisible to client-side users.
- PHP has performance advantage over Perl which is another server side scripting language.
- PHP is a cross-platform scripting language. It works in Windows, Linux and other environment while ASP is not capable of.
- C language can be implemented as part of the script.

Disadvantages:

- A lot of strain is put on the server resulting from the nature of the server side scripting language. The server might fail to handle things properly when there are a large number of concurrent requests, and complex enough scripts. However, this is not a real concern because the PHP parser is fast enough to make up for this drawback.
- PHP is slower than an equivalent C-program when making a C-program in the script because it is a parsed language.

4.3 Platform: Redhat 9.0

EPR is designed on the open source leader Redhat Linux. Redhat has pervasive open source technology. It runs systems of all sizes. Redhat aims to power enterprise mission-critical computing [21]. The main reason why Linux is used in this project is because it provides superior security compared to Windows systems. Also, Linux is more a set of infinitely rearrangeable operating system than Windows, which is a unified operating system [25].
4.4 Web Server: Apache version 2.0

EPR is run on Apache version 2.0. Apache, Microsoft, SunONE and Zeus are the top web server developers in the industry. According to the March 2004 survey conducted by Netcraft, Apache has the highest market share [26]. The Apache Web Service project was developed by Apache Software Foundation, and provides an open, collaborative software project.

The Apache HTTP Server Project develops and maintains an open-source HTTP server for UNIX and Windows NT systems, and other modern operating systems [19]. Since April, 1996, Apache has become the most popular web server over the Internet. Apache Internet service is used among more than 64% of the web sites, as quoted in the October 2003 Netcraft Web Server Survey [20].

4.5 Web Database: MySQL --- Creating A High-Quality Database Useful for Health Care Staffs

Moving towards computer-based hospital information system, medical knowledge has been shared in various online documentation forms. It is more convenient for health care staffs to receive accurate, current medical knowledge online than in the traditional form. Therefore, a high-quality, comprehensive, practical, up-to-date medical database is needed. MySQL is a high-quality database. PHP in particular is built from the ground up with MySQL database functionality.

The MySQL database server has a reputation of ease of installation, maintainability, configuration, and speed. EPR depends on MySQL Server 4.0 and MySQL Graphic Client — MySQL Control Center.

MySQL is the world's most popular open source database with extremely fast and easy to customize features. The database management system has unmatchable speed, compactness and stability. It has extensive reuse of code within the software and rich functionality. One of its unique features is that it runs queries with strict transaction control or with ultra-fast transactionless disk access by separating the core server and the
storage engine [34].

- The MySQL database server is available for free under the GNU General Public License (GPL) as long as it is not redistributed. MySQLCC works alongside the MySQL database server as a GUI client, which is very user friendly.

- MySQLCC has the easy feature to create/delete databases or tables, write and execute SQL queries, examine table contents directly, and back up server setup. It also supports and works with both local and remote MySQL database servers, tables of all types, and MySQL® Connector drivers.

- MySQL Connector database drivers provide the server with high-performance connectivity. There are drivers for Java platform, for ODBC applications, and for C++ languages. A cross-platform support is capable of twenty-four different platforms.

- Drivers are under open source license. They are free of charge for non-commercial use. Commercial licenses need to be purchased otherwise [35].
5. EPR Security

5.1 Security Issues in the Hospital Information System (HIS)

There are various Internet functions currently applied throughout the hospital information system. Functions such as, transferring patients’ medical information, retrieval of up-to-date records, health care discussion forums, online medical textbooks, and sharing of common medical knowledge. Different functions are applied by different means. Means such as, file transfer protocol (FTP), electronic mail service, the world wide web, database retrieval, word-of-mouth communication, and much more [34]. The Internet provides public access to physician contact information, within a hospital or a clinic, as well as personal email among the health care staff.

There are a number of high technique functions that might emerge at any time with the rapid computer information technology development. For instance, tele-surgery is one of them [36]. Tele-surgery is surgery done by physicians with the assistance of computer technology to operate on patients in areas which are dangerous or inaccessible for human to perform.

Since the Internet is essential for today’s hospital information systems, the discussion of security issue is inevitable. However, there are measures to be used through encryption, firewall, digital signature, and authentication.

5.2 Privacy and Confidentiality of Electronic Data

Now that EPR data are becoming accessible for different purposes, as mentioned earlier, it is of great importance to well protect those data which concerns patients’ privacy, and the professional interests in the health care industry [10]. Law enforcement is one approach to electronic medical data protection. In Europe, the Treaty for the Protection of Human Rights and Fundamental Freedom [16] and the European law [17] have anchored the privacy right in order to prevent electronic medical data from being hampered for goals other than patient care. Yet, the absolute prevention of the improper
use of electronic medical data will be extremely difficult. Some sense of the improper use will not be avoided.

On one hand, modern health care often requires shared care by different physicians rather than care by a single one. Protecting the privacy of a patient's data depends on every single medical professional in the health care industry. On the other hand, privacy is not a privilege. It is a right. For these reasons, ensuring the right to privacy is just as critical as implementing regulations on the secrecy of patient data. It is a must that in all EPR systems proper measures are designed for protection of patients’ privacy as well as their medical data.

5.3 Security Measures in EPR

The key measures applied in EPR are encryption and authentication.

- The password is encrypted with md5() method. Each password is encrypted as a 32-character string, which is unreadable and unrecognizable by database administrators or others who maintain the database.
- All the variable values passed through URL are encoded as well, and it is decoded upon receiving.
- Each time a person logs in, the login information will be tested for authentication. An invalid user will not be permitted to access the application.
- The session handling mechanism is provided for each authorized user. Each user has a maximum amount of time for access.

It addition, EPR offers:

- Availability - Electronic Patient Record doesn't require the physical presence of the records. Here, “physical presence of the records” means the actual original copies of the records. The file is accessible as long as there is an Internet connection and authorization.
- Authentication - Authorization is highly required in Electronic Patient Record application. Data records on file require specific authorization for the purpose
of confidentiality.

- **Confidentiality** - The content of the data is not exposed to unauthorized individuals.
- **Integrity** - The data records are not altered by unauthorized users.

In summary, the encryption and authentication measures prevent creation of fraudulent accounts. The confidentiality and integrity measures assist in the guarantee of patient privacy law. With the availability measure, EPR system provides convenient access for authorized users.
6. Conclusions and Future Development

6.1 Advantages and Disadvantages of EPR

EPR is a well-designed application for the hospital information system. Like anything else, it has its advantages and disadvantages. The advantages of EPR are:

- EPR is affordable and cost effective since personal computers and workstations have become inexpensive.
- EPR records and retrieves patient medical history and treatment details in an easy storage and easy search manner.
- The structured data entry designed in EPR provides an efficient tool for enhancing data completeness, testing for data reliability [13], and information accuracy. SNOMED is the standard medical term reference for EPR project.
- EPR is a physician-centered application. Physicians, as one of the six users, are granted the most powerful functionalities on EPR implementation since they play the most important role in the health care system.
- EPR is also a nurse-centered application. Nurses are granted quite a few capabilities on EPR considering their critical roles in patient care. Nurses are just as important as all the other users.

The disadvantages of EPR are:

- Since EPR is World Wide accessible, the security issue via the Internet is a concern. Yet, with the progress in regulations over the network communication, there are measures that can be done to ensure the security.
- The education of EPR users is required. A training program for EPR application users is a must.

6.2 Potential Development

A complete hospital information system will integrate the clinical system, the health care subsystem, the financial system, the administrative system and the other systems into one
centralized system. Here, the design of EPR only focuses on the clinical system, which implements free/coded text on patient records. In the future, EPR can be extended to digital image processing for cardiology, electronic data exchange between physicians of the same discipline, and data retrieval for clinical studies.

Another possibility is to involve pharmaceutical entities and insurance companies as part of the system. A pharmaceutical entity will be able to receive an alert email to prescription order on behalf of the patient. It then prepares the drug. The intention is to provide a wait-free environment for patients.

6.3 Future Goals

One of the challenging issues is the issue of effective user-computer interfaces. Physicians, as the users of the system, simply perform data entry (e.g., diagnosis, prescription) as well as information retrieval. The current EPR system has not realized the benefits of interactive, on-line decision support for physician users. The "cognitive processes involved in human-computer interactions" [9] must be made in the future development. Interface designing must be more intuitive, more acceptable [15] and more user-friendly for health care users. Ultimately, changes need to be made in how the system looks and how system users interact with the computer. Good design of templates and useful and practical default values are also needed, which will improve operation efficiency.

There are always changes in HIS users. Users in HIS have dramatic impacts on the applications and the desired interfaces. All these changes need to be addressed and realized in current and future HIS applications.

Publishers of medical textbooks should promote the electronic version of their papers and books into available styles such as HTML or SGML. The health care staffs should be provided with comprehensive, high-quality medical knowledge in the form of online medical publications. One way or the other, a good online medical database is highly desired for reference to decision making in diagnosis/prescription.
As computer utilization in the health care industry continues to expand, nurses play more challenging roles. The hospital information system reflects a nurse’s perspective. According to the American Association of Colleges of Nursing, 30 states had shortages of registered nurses in 2002 [27]. The average age of nurses are around 46 [28]. A successful design of a nurse application might be able to help with the shortage problem.
REFERENCES


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University of South Florida, College of Medicine.


APPENDIX – Table Descriptions

create table USERS (  
user_ID CHAR(8) NOT NULL,
lastname CHAR(30) NOT NULL,
firstname CHAR(30) NOT NULL,
MI CHAR(2)
SSN CHAR(11) NOT NULL,
auth_level CHAR(2) NOT NULL,
login CHAR(13) NOT NULL,
password CHAR(13) NOT NULL,
password2 CHAR(13),
PRIMARY KEY(user_ID)
);

create table PATIENT (  
p_ID CHAR(13) NOT NULL,
p_lastname CHAR(30) NOT NULL,
p_firstname CHAR(30) NOT NULL,
p_MI CHAR(2),
ssn CHAR(11) NOT NULL,
Dr_ID CHAR(13) NOT NULL,
Dr_name CHAR(10) NOT NULL,
visit_reason CHAR(10) NOT NULL,
visit_date CHAR(10) NOT NULL,
discharge_date CHAR(10),
PRIMARY KEY(p_ID),
FOREIGN KEY(Dr_ID) references PHYSICIAN
);

create table PHYSICIAN (  
ID CHAR(13) NOT NULL,
last CHAR(30) NOT NULL,
first CHAR(30) NOT NULL,
MI CHAR(2),
ssn CHAR(11) NOT NULL,
title CHAR(13) NOT NULL,
specialty CHAR(50) NOT NULL,
office CHAR(50) NOT NULL,
phone CHAR(13) NOT NULL,
email CHAR(50),
PRIMARY KEY(ID)
);
create table NURSE (  
  ID CHAR(13) NOT NULL,  
  first CHAR(30) NOT NULL,  
  last CHAR(30) NOT NULL,  
  MI CHAR(2),  
  ssn CHAR(11) NOT NULL,  
  login CHAR(13) NOT NULL,  
  date_start CHAR(10) NOT NULL,  
  date_end CHAR(10),  
  PRIMARY KEY(ID)  
) ;

create table DIAGNOSIS (  
  ID CHAR(13) NOT NULL,  
  p_ID CHAR(13) NOT NULL,  
  p_name CHAR(30) NOT NULL,  
  primary CHAR(50) NOT NULL,  
  SNOMED_p CHAR(30),  
  provisional CHAR(50),  
  SNOMED_s CHAR(50),  
  Dr_ID CHAR(13) NOT NULL,  
  Dr_name CHAR(30) NOT NULL,  
  comments CHAR(50),  
  date CHAR(10) NOT NULL,  
  PRIMARY KEY(ID),  
  FOREIGN KEY (p_ID) references PATIENT,  
  FOREIGN KEY (Dr_ID) references PHYSICIAN  
) ;

create table PRESCRIPTION (  
  ID CHAR(13) NOT NULL,  
  p_ID CHAR(13) NOT NULL,  
  p_name CHAR(30) NOT NULL,  
  Dr_ID CHAR(13) NOT NULL,  
  Dr_name CHAR(30) NOT NULL,  
  prescription CHAR(50) NOT NULL,  
  comments CHAR(50) NOT NULL,  
  date CHAR(10) NOT NULL,  
  PRIMARY KEY(ID),  
  FOREIGN KEY (p_ID) references PATIENT,  
  FOREIGN KEY (Dr_ID) references PHYSICIAN  
) ;

create table PERSONAL (  
  patient_ID CHAR(13) NOT NULL,  
  PRIMARY KEY(patient_ID)  
) ;
lname                CHAR(30) NOT NULL,
fname                CHAR(30) NOT NULL,
 MI                     CHAR(2),
DOB                 CHAR(10) NOT NULL,
Marital_stat      CHAR(10) NOT NULL,
diet                   CHAR(30)
employer          CHAR(30),
supervisor        CHAR(30),
work_phone     CHAR(18),
home_phone    CHAR(10),
cell                   CHAR(10),
email                CHAR(30),
fax                    CHAR(10),
mailing_addr   CHAR(50) NOT NULL,
contact_person CHAR(30) NOT NULL,
contact_phone  CHAR(18) NOT NULL,
contact_email   CHAR(30),
relastionship     CHAR(20) NOT NULL,

 PRIMARY KEY(patient_ID)
);

create table SCHEDULE_NURSE (    ID                     CHAR(13) NOT NULL,
nurse_ID           CHAR(13) NOT NULL,
nurse_fname     CHAR(30) NOT NULL,
nurse_lname      CHAR(30) NOT NULL,
 MI                     CHAR(2),
Dr_ID                CHAR(13) NOT NULL,
Dr_title              CHAR(30) NOT NULL,
Patient_ID         CHAR(13) NOT NULL,
Patient_lname    CHAR(30) NOT NULL,
Patient_fname   CHAR(30) NOT NULL,
Patient_room     CHAR(30),
Start                   CHAR(10) NOT NULL,
End                    CHAR(10),
Date                   CHAR(10) NOT NULL,
 PRIMARY KEY(ID),
FOREIGN KEY(nurse_ID) references NURSE,
FOREIGN KEY(Dr_ID) references PHYSICIAN,
FOREIGN KEY(patient_ID) references PATIENT
 );